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Indian Standard

GUIDE FOR INTER-CONVERSION OF VALUES FROM ONE SYSTEM OF UNITS TO ANOTHER

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 7 *January* 1957

Indian Standard

GUIDE FOR INTER-CONVERSION OF VALUES FROM ONE SYSTEM OF UNITS TO ANOTHER

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CONTENTS

PAGE

0. FOREWORD 3

1. SCOPE 5

2. TERMINOLOGY 6
   2.1 Decimal Places 6
   2.2 Significant Figures 6
   2.3 Significant Part 7
   2.4 Order of Magnitude 7
   2.5 Fineness of Rounding 8

3. CONVERSION FACTORS 9

4. SIGNIFICANCE OF GIVEN VALUES 10
   4.1 Exact Terminating Values 10
   4.2 Inexact Values for Exact Quantities 10
   4.3 Inexact Values Subject to Inherent Uncertainty ... 11
   4.4 Dimensional Designation Values 20
   4.5 Monetary Values 22

5. PROCEDURE FOR CONVERSION 26
   5.1 Rules 26
   5.2 Monetary Values 28

APPENDIX A — TABLE IV DERIVED CONVERSION FACTORS AND COMMONLY USED UNITS 30

APPENDIX B — BRIEF SUMMARY OF INSTRUCTIONS FOR REWRITING VALUES BEFORE CONVERSION 32

Indian Standard

GUIDE FOR INTER-CONVERSION OF VALUES FROM ONE SYSTEM OF UNITS TO ANOTHER

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 8 December 1956 on approval by the Engineering Division Council of the draft finalized on 19 October 1956 by the Engineering Standards Sectional Committee.

0.2 The Report of the Indian Standards Institution Special Committee on Weights and Measures, submitted in 1949 recommending to Government of India the adoption of the Metric System, has now been fully considered and examined by the Planning Commission, and on its recommendation the Government has generally accepted the Report. The preparation of this Indian Standard Guide for Inter-Conversion of Values from One System of Units to Another has become particularly necessary to implement the decision of the Government to adopt the metric system as the only system of weights and measures for the country (within the period of 10 years). The need for such a standard has existed for a long time in India, as also in other countries, wherever more than one system of units for measuring similar quantities has been in use. Conversion of values from one system to another raises issues of interchangeability of parts, precision of statement, and other rigid criteria.

0.3 So far as is known, in no country has this task been tackled from standards point of view in a general manner. From the early beginnings of the Indian Standards Institution during the course of drafting specifications on the basis of known technological data collected from diverse sources, and in line with the standards from different countries using different systems of units, it had become necessary to inter-convert values from one set of units to another. Furthermore, in view of the expectation that the country would adopt the metric system at one time or another, it was decided that in all Indian Standards, numerical values should be specified either in metric units or, failing that, in terms of the units most commonly used in the particular industry concerned, but in the latter case it was required that metric equivalents of values be added within brackets. All these needs for inter-conversion of values led to the development of certain ideas which were gradually put into use in the day-to-day working of the ISI Directorate. In due course, these ideas began to take concrete form. This standard, in fact, is the outcome of these developments, and it may rightly be claimed that the procedures advocated in it have been tried out in practice for several years within the Institution.

0.4 One of the first published contributions of value bearing on this subject appeared in the Overseas Edition of Machinery Lloyd of 23 April 1955. The article was by L. W. Nickols of the Metrology Division of the National Physical Laboratory of UK, and was entitled "The Inter-Conversion of Inch and Metric Sizes in Engineering Drawings" (*see also* ISI Bulletin, November 1955). A study of Nickols paper will indicate that the limited problem of inter-conversion of linear dimensions with special attention to interchangeability of parts has been ably tackled and the procedure proposed is quite satisfactory. But having been designed to deal with the limited problem of linear dimensions, it does not readily lend itself to generalization for use in dealing with inter-conversion of quantities other than linear.

0.5 This Standard Guide, however, puts forth the Indian Standard procedure, which is general enough for use in the inter-conversion of all quantities from any set of units to any other. It also discusses in some detail the significance of stated values and shows how to assess their significance for the purpose of conversion. It incidentally lays down a standard practice for stating and specifying values, so as to make their significance self-evident beyond doubt and not subject to different interpretations.

0.6 In stating the procedure, a new concept designated as the *significant part* of a number has been introduced (*see* **2.3**). It must be understood, however, that this term has been used only because no other better term was available. The concept itself appears to be new, and the term may be useful in teaching the use of logarithms to students; for in looking up the logarithm of a number it is the significant part of the number that is used to obtain the mantissa.

0.7 In preparing this standard, reference has been made to the following:

B.S. 350 : 1944 CONVERSION FACTORS AND TABLES.

B.S. 1957 : 1953 PRESENTATION OF NUMERICAL VALUES.

INCLUSION OF EQUIVALENT METRIC VALUES IN SCIENTIFIC PAPERS. National Physical Laboratory, Teddington, UK. 1948.

NICKOLS, L. W. *loc. cit.* (*see* **0.4**), ALSO IEC Doc 39 (UK) 30.

ADAMS, G. C. PRINCIPLES AND PRACTICE GOVERNING INTERCHANGEABILITY AND SPECIFICATION OF MANUFACTURING LIMITS OF SIZE, AS INFLUENCED BY STATISTICAL CONSIDERATIONS. PROC. (A) Inst. Mech. Eng., Vol. 167, No. 2, pp. 154-169 (1953).

ASTM DESIGNATION E 29-50 RECOMMENDED PRACTICE FOR DESIGNATING SIGNIFICANT PLACES IN SPECIFIED VALUES.

DOCUMENT ISO/TC 69 (SECRETARIAT-6) 6 GENERAL DEFINITIONS RELATING TO CHEMICAL AND PHYSICAL TEST RESULTS.

DOCUMENT ISO/TC 12 (SECRETARIAT-53) 134E TABLES OF QUANTITIES AND UNITS.

DOCUMENT ISO/TC 12 (SECRETARIAT-70) 197E DRAFT ISO RECOMMENDATION NO. 97 FUNDAMENTAL QUANTITIES AND UNITS OF THE MKSA SYSTEM AND QUANTITIES AND UNITS OF SPACE AND TIME.

THE STANDARDS OF WEIGHT ACT, 1939. (ACT IX OF 1939).

THE MEASURES OF LENGTH ACT, 1889. (ACT II OF 1939).

THE INDIAN COINAGE (AMENDMENT) ACT, 1955.

0.8 In the use of this Standard Guide, reference to the following Indian Standards will be required:

*IS : 2-1949 RULES FOR ROUNDING OFF NUMERICAL VALUES

†IS : 3-1949 INCH-MILLIMETRE CONVERSION FOR INDUSTRIAL USE

‡IS : 696-1955 CODE OF PRACTICE FOR GENERAL ENGINEERING DRAWINGS

*IS : 786-1956 CONVERSION FACTORS AND CONVERSION TABLES.

0.9 During the next 10 to 15 years, when the country will be effecting the change over from the existing sets of units of weights and measures to the metric units, it is hoped that this standard will provide the necessary basis for the training and guidance of the personnel directly concerned with the detailed work of conversion, and will help the engineer, designer, technologist and management in respect of detailed dimensions on drawings, and in specifying quantities, reporting figures, etc.

1. SCOPE

1.1 This standard is intended to serve as a guide in converting numerical values of physical quantities from one system of units of measurement to another system of units; in particular, it should assist the designer and the draftsman in converting dimensions and tolerances on engineering drawings from inches to millimetres.

1.1.1 It also deals with the conversion of monetary values of interest to administrators, traders and industrialists.

1.2 The significance of specified values and how to interpret them for conversion are also discussed.

---

*Since revised.

†Since withdrawn.

‡Second revision in 1972.

2. TERMINOLOGY

2.0 For the purpose of this standard the following definitions shall apply.

2.1 Decimal Places — A value is said to have as many decimal places as there are number of figures in the value, starting from the decimal point and ending with the last right-most figure in the value.

For example:

Value	*Decimal Places*
0·029 50	5
21·029 5	4
2 000·000 001	6
291·00	2
$10{\cdot}32 \times 10^3$ (*see* Note 2)	2

NOTE 1 — In writing down values it is recommended for clarity of expression that

a) the figures on either side of the decimal are grouped in threes with clear gaps in between as in the above examples, and

b) when the value is less than unity, a zero precedes the decimal point.

NOTE 2 — For the purpose of this standard, the expression $10{\cdot}32 \times 10^3$ should be taken to consist of two parts, the value proper which is 10·32 and the unit of expression for the value, 10^3.

2.2 Significant Figures — A value is said to have as many significant figures as there are number of figures in the value, counting from the left-most *non-zero* figure and ending with the right-most figure in the value.

For example:

Value	*Significant Figures*
0·029 50	4
0·029 5	3
10·029 5	6
2 000·000 001	10
5 677·0	5
567 700	6
$56{\cdot}77 \times 10^2$	4
0 056·77	4

NOTE 1 — According to this definition all zeros appearing at the end of an integer, or of a decimal fraction, are counted as significant. This follows from the practice adopted in Indian Standards for specifying values (*see also* 4). In other words, care is taken that any specified value in an Indian Standard terminating *in one or more zeros* implies that the last zero has a significance in the determination of the value and in its *comparison with other values*. The methods of measurement, analysis, tests, etc, employed must have the requisite degree of accuracy to impart significance to the last figure in the value, whether it is zero or not.

For example:

a) *If the minimum strength of a material is to be*, say, 20 000 grams per square millimetre and the accuracy of measurement is of the order of 50 g/mm², then the specified value may be written as 20·0 kg/mm² or 20·0×10³ g/mm² and not as 20 000 g/mm²; in other words, the number of significant figures in the result of a test should be only three, because the method of determination is such that fourth figure cannot in practice have any utility or significance.

b) A dimension may be specified as 1 530 mm, or 153·0 cm, or 1·530 metres or even 1·530×10³ mm, if the accuracy of measurement is *intended to be of the order of* 0·5 or 1 mm. On the other hand, if such a dimension is specified as 153 cm or 1·53 *metre, it* will imply an accuracy of a lower order of magnitude, namely, 5 mm or 1 cm.

NOTE 2 — Thus the *number of significant* figures in a value in the absence of other supplementary information, such as the tolerance or error, is taken to be an indication of the accuracy of the physical quantity involved, that is at least so in Indian Standards issued during the recent years. In general engineering practice, however, due to the absence of a mutually agreed convention, such a significance is not *always* attached to a stated value, although it is highly desirable that the practice *followed in Indian* Standards be adopted generally.

2.3 Significant Part of a number consists of the significant digits occurring in the value written down as an integral number without a decimal point and without the non-significant zeros.

For example:

Value	*Significant Part*
0·005 690	5 690
0·005 69	569
10·029 5	100 295
$56{\cdot}77 \times 10^2$	5 677
$3{\cdot}0 \times 10^6$	30
2 000	2 000
2×10^3	2
076·00	7 600

2.4 Order of Magnitude — Two numbers are referred to in this standard as having the same order of magnitude if the greater one is not more than ten times the smaller.

For example:

a) The following pairs of values are of the same order of magnitude:

9·6 and 96
2·15 ,, 10
1·69 ,, 0·497 2
1 000 ,, 101·35
1 756 049 ,, $15{\cdot}2 \times 10^5$

b) But the following pairs are not of the same order of magnitude:

99	and	9·8
25	,,	251
1	,,	16
$162{\cdot}9 \times 10^3$	,,	15 000

c) Combining the concept of significant part (*see* **2.3**) with that of order of magnitude, it may be noted that the significant parts of the pairs of values, given below, are of the same order of magnitude, though the values themselves may or may not be so:

Values			*Significant Parts*		
23·4	and	4·36	234	and	436
0·005 6	,,	35·1	56	,,	351
10×10^6	,,	4·1	10	,,	41

2.5 Fineness of Rounding is the unit to which a value is rounded off.

For example:

The value 125·152 6 when rounded off by using various degrees of fineness of rounding yields the rounded values as indicated below:

Fineness of Rounding	*Rounded off Value*
0·000 5	125·152 5
0·001	125·153
0·002	125·152
0·005	125·155
0·01	125·15
0·1	125·2
1	125
10	$1{\cdot}3 \times 10^2$
100	1×10^2

NOTE 1 — While rounding off values *IS : 2-1949 shall be followed in all cases, with the additional rule that when fineness of rounding is not unity in the last place retained, but, say, it is *n*, then, if the figure to be discarded falls exactly midway between two alternatives, that rounded value shall be chosen which is an integral multiple of 2 *n*.

For example:

VALUE	FINENESS OF ROUNDING	ROUNDED VALUE
1·75	0·5	2·0
2·70	0·2	2·8
3 025	50	$30{\cdot}0 \times 10^2$
9 075	50	$91{\cdot}0 \times 10^2$
35 750	100	$35{\cdot}8 \times 10^3$

Fineness of rounding other than unity in the last place retained would not be generally required for use in the rules for conversion given in this Guide.

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*Since revised.

3. CONVERSION FACTORS

3.1 The principal conversion factors for use in the inter-conversion of commonly occurring quantities and for calculating other conversion factors of multiple and sub-multiple units and the conversion factors of derived quantities shall be those given in Table I.

TABLE I PRINCIPAL CONVERSION FACTORS

NON-METRIC UNIT	METRIC EQUIVALENT	RECIPROCAL
1 inch	25·4 millimetres (exact)	0·039 370 07 in/mm
1 Imperial gallon	4·545 96 litres or 4·546 09 cubic decimetres*	0·219 976 Imp gal/l or 0·219 969 Imp gal/cu dm
1 US gallon	3·785 29 litres or 3·785 43 cubic decimetres*	0·264 180 US gal/l or 0·264 173 US gal/cu dm
1 pound (avoirdupois)	0·453 592 4 kilograms	2·204 622 lb/kg
1 seer†	0·933 104 kilograms	1·071 692 sr/kg
1 Fahrenheit degree‡	0·555 555 6 Centigrade degree	1·8 deg F/deg C (exact)

*It should be noted that the latest measurements have revealed a significant measurable difference between the metric capacity unit litre defined as the volume of 1 kg of water under certain conditions and the cubic unit of volume of one cubic decimetre based on the standard of length metre. Thus, 1 litre = 1·000 028 cubic decimetre or 1 ml = 1.000 028 cc.

†This seer is the standard seer defined in the Standards of Weight Act, 1939, as being equal to 14 400 grains, with a multiple unit of maund equal to 40 seers and sub-multiples of 80 tolas and 16 chhataks to one seer.

‡In converting temperature values, it should be borne in mind that zero degree point on Centigrade Scale corresponds to 32 degree point on Fahrenheit Scale.

3.2 In Appendix A, Table IV, are given derived conversion factors for commonly used units, such as horsepower, energy, density, weight per unit area, etc.

3.3 More comprehensive and extended tables have been published in *IS :786-1956 which are intended to facilitate the work of engineers, technologists, students and others concerned constantly with tasks involving inter-conversion of quantities.

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*Since revised.

4. SIGNIFICANCE OF GIVEN VALUES

4.0 For the purpose of this standard, values in general may be divided into the following categories and sub-categories.

I *Exact Terminating Values*

II *Inexact Values for Exact Quantities*

III *Inexact Values Subject to Inherent Uncertainty*
  a) Unqualified Single Number Values
  b) Maximum and Minimum Single Number Values
  c) Multiple Values including Statement of Precision

IV *Dimensional Designation Values*
  a) Standardized Dimensional Designations
  b) Non-Standard Dimensional Designations

V *Monetary Values*
  a) Simple Monetary Values
  b) Complex Monetary Values

4.1 Exact Terminating Values are expressed to as many significant figures as may be necessary to give the complete value, without any approximation or uncertainty or tolerance.

For example:

a)	100	centimetres in a metre
b)	2·54	centimetres in an inch
c)	1.728	cubic inches to a cubic foot
d)	1.8	deg F equivalent to 1 deg C
e)	100	years in a century
f)	12	units in a dozen
g)	5	sides to a pentagon

It will be seen that such values generally constitute a category of conversion factors of one sort or another.

They will thus not require to be converted from one system of units to another.

4.2 Inexact Values for Exact Quantities include exactly defined values, pure numbers and conversion factors, which, when stated as a decimal fraction, have of necessity to remain inexactly stated, but the decimal fraction represented therein may be carried to as many places as may be necessary to attain the degree of accuracy required for the immediate purpose in view.

For example:

a) $\log_{10} 2$ = 0·301 030...

b) $\sqrt{2}$ = 1·414 21 ...

c) π = 3·141 593...

d) e = 2·718 282...

e) 1 deg F = 0·555 555... deg C or 0·556 deg C

f) 1 mm = 0.039 370 1... in

As for values in Category II, it will again be noted that such pure numbers and conversion factors will not be required to be converted from one set of units of measurement to another.

4.3 Inexact Values Subject to Inherent Uncertainty include most of the values representing physical quantities and certain dimensionless quantities such as percentages and ratios which may represent the result of a measurement, estimation or calculation. These may be subdivided into the three sub-categories as stated under **4.0**.

4.3.0 Dimensionless quantities falling in this category such as percentages, ratios, parts per million, Reynold's Number and the like require no conversion from one set of units to another: they are, therefore, omitted from further discussion.

4.3.1 *Unqualified Single Number Values* are those which are stated without qualification as to being maximum or minimum and/or without any reference to a desired or implied accuracy or uncertainty or tolerance.

For such values supplementary information is usually available regarding the degree of accuracy required or implied according to trade usage or engineering practice. Such information should be made use of in converting these quantities. In the absence of any guidance as to the degree of accuracy implied, the accuracy of the value should be assumed to be ±0·5 of the unit in the last significant place given. In applying this rule, however, considerable caution should be exercised to preserve the accuracy necessary to be maintained in conversion.

For example:

In the absence of a clue to the possible or intended accuracy,

a) a dimension specified on a drawing as 0·75 in may be taken to be accurate to ±0·005 in,

b) a distance between two points on a plan given as 15 miles 3 furlongs may be taken to be accurate to ±0·5 furlong,

c) the tolerance of the length of a battery lead specified as 4½ inches in a specification may be assumed to be ±0·25 in (*see also* **4.3.1.2**),

d) a *p*H measurement test result of 2·5 may be accurate to ±0·05 units of *p*H.

4.3.1.1 The underlying reason for the above rule for the assumed accuracy of unqualified values becomes clear when the origin of a stated or specified figure is considered. If a higher order of accuracy or tolerance than that represented by one-half of a unit in the last significant place were desired or intended, the author of the figure should have either carried the figure to another significant place or stated its tolerance or error. In the absence of any such statement, the user of the figure is entitled to assume that the author has given the figure accurate to the nearest unit in the last significant place. At the time of origin an adjustment of this type could be made only to the extent of ±0·5 unit of the last significant place, and it is reasonable to assume this order of accuracy for figures of this category. There is, however, one drawback in this assumption, that most authors, writers of specifications and designers are likely to drop the zeros at the end of a decimal fraction, even if significant, and to retain zeros at the end of an integral number, even if non-significant. As discussed in the Notes under **2.1** and **2.2**, such practice is contrary to the recognized practice followed in writing Indian Standard Specifications. Until, however, the recommended practice of retaining all significant zeros and eliminating all non-significant zeros becomes commonly adopted by all concerned, it is essential that this rule of half a unit accuracy in the last significant figure be applied with extreme caution.

A brief discussion of the examples given under **4.3.1** will help clarify this point.

a) It is obvious that the 0·75 in dimension stated on a drawing without tolerance could not have been intended by the designer or draftsman to be 0·74 or 0·76, for he would have stated it as such. Since, according to *IS : 2-1949, the values 0·745 and 0·755 would be rounded respectively to 0·74 and 0·76 and 0·745 + and 0·755 — would both be rounded to 0·75, it is reasonable that the designer's intention was to imply an accuracy of ±0·005 in his statement of the 0·75 in dimension.

   It may be objected that the designer might have stated 0·75 in but meant to imply 0·750 in or even 0·750 0 in. Such a practice is not unknown, but it is normal to state a tolerance when dimensions are intended to be so exact. The case of toleranced dimensions will be treated later under **4.3.3**. Furthermore, according to Indian Standard practice, it is recommended (*see also* **2.2**) that whenever a zero is intended to be significant it shall be included and whenever it is not included it may be taken not to be significant. Before, however, the Indian Standard practice becomes generally adopted, users of this Standard Guide will have the responsibility of exercising their judgement as to the exact intention of the designer in respect of an untoleranced dimension, which intention will not always be too difficult to discover when the dimension in question is examined carefully in respect of its significance and importance in relation to other associated dimensions and to the context.

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*Since revised.

b) A distance of 15 miles 3 furlongs indicated may be the result of a measurement, in which case it is clear that the figure of 3 furlongs is most likely the result of rounding off the measured distance to the nearest furlong. Thus, the presumption of ±0·5 furlong accuracy may be quite justified. But, if this distance is given on a construction plan where the two points in question are to be located by measurement in the field, then under present-day practice the accuracy intended for this measurement would naturally be that attainable by the usual method and equipment employed for measuring off this particular distance. That is to say, the accuracy implied would be much better than ±0·5 furlong; it may be ±one yard or one foot, or sometimes even better than that, say ±one inch, depending entirely on the requirements of the job concerned. In such cases, it must be realized that the dimension in question cannot be taken *strictly* to belong to this category of unqualified values but may be classed in the category of precise dimensions discussed under **4.3.3**.

c) The 4½ in length of battery lead called for in a specification may safely be taken to be between 4¼ and 4¾ in because it will be recognized that in practice a ¼ in variation up or down is not going to make the battery difficult of assembly or use. But, then, if the dimension for such a lead is specified, say, 4 in, we shall have to be careful in assuming its permissible variation to be ± ½ in. *Therefore, there is considerable room for caution in the use of this general rule even in cases of relatively unimportant dimensions.* In general, it is recommended that for vulgar fractions directions given under **4.3.1.2** may be followed.

d) In case of a statement of a result of measurement such as the *p*H, chemical composition, strength of a test piece, etc, there is usually little danger of going wrong in assuming the order of accuracy recommended here. This is so because reporting authorities are not prone to state the result of a test in fewer numbers of significant figures than actually obtained by making a measurement or as may be derived through calculations based on measured values. They are, on the contrary, likely to state more significant figures than may be actually justified by the accuracy of the method used.

4:3.1.2 In case of vulgar fraction values, particularly for inches, it is not *always* possible to assume the accuracy to be ±½ of the fractional part of the value as explained in example (c) above. Vulgar inch fractions in general are known to imply a much higher degree of accuracy than this, but the order of magnitude of the accuracy depends mostly on the type of dimension involved. For example, if a directive required 4½ in blanks to be cut off from a rod for further machining, it certainly implies a higher degree of accuracy than ±¼ in as may readily be imputed to a battery lead length of example (c) above. In all cases of vulgar fractions, therefore, before proceeding to convert a value to metric or other units, it is advisable to convert the vulgar fraction in question to a decimal fraction first and express it to such number of places as may be considered adequate to express the degree of accuracy appropriate for the particular job in hand. For example, the 1½ in blank for machining may be taken to be 1·5 in so that its implied accuracy is ±0·05 in.

According to *IS : 696-1955 an unqualified vulgar fraction dimension on a drawing may be taken to be accurate to $\pm\frac{1}{32}$ in. This may serve as a suitable guide in most cases except where a dimension is carried to $\frac{1}{64}$ in. A dimension carried to $\frac{1}{32}$ in may also sometimes lead to doubt. Influence of surface texture on attainable accuracy should also be borne in mind. In all such cases, therefore, the above rule of converting the vulgar fraction dimension to decimal fraction and *assigning it the appropriate* precision before conversion will be found most useful (*see also* **4.3.3**).

In converting vulgar fractions, the use of †IS : 3-1949 will facilitate the work of obtaining exact decimal equivalents of vulgar inch fractions both in inches and millimetres.

4.3.1.3 Conversely, the above rule should also be adopted in specifying a value or reporting a test result without tolerance limits or estimated error, when care should be taken that only the last significant figure is in doubt to the extent of not more than ±0·5 unit in the last significant place, and, further, that all significant zeros should be retained and all non-significant zeros dropped.

4.3.1.4 Assuming that in stating the unqualified single number values, the practice recommended under **4.3.1.3** has been followed, then the maximum and minimum limits of relative or percentage errors of such values become a direct function of the number of significant figures retained in the value. On this basis, the range of percentage errors to three significant figures will be within the limits given in Table II.

4.3.2 *Maximum and Minimum Single Number Values* include specification values, values expressing result of an experiment, expectation of an operation, limit, capacity or possibility of achievement, etc.

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*Second revision in 1972.

†Since withdrawn.

TABLE II LIMITS OF ERRORS IN UNQUALIFIED SINGLE NUMBER VALUES

(*Clause* 4.3.1.4)

NUMBER OF SIGNIFICANT FIGURES IN VALUE	RANGE OF SIGNIFICANT PARTS OF VALUE		LIMITS OF PERCENTAGE ERROR	
			Maximum	Minimum
1	1 to	9	50·0	5·56
2	10 ”	99	5·00	0·505
3	100 ”	999	0·500	0·050 1
4	1 000 ”	9 999	0·050 0	0·005 00
5	10 000 ”	99 999	0·005 00	0·000 500
n	10^{n-1} ”	$10^{n}-1$	$5 \times 10^{2-n}$	$5 \times 10^{1-n}$*

*This expression applies to larger value of *n*; for all values including smaller values of *n* the general expression for minimum percentage error will be $50 \div (10^{n} - 1)$.

In some cases, tolerance limits or uncertainty of estimates are sometimes found associated with maximum and minimum values, but really they can have no significance and, as a general rule, should be avoided in stating such values. For instance, there is no point in stating that the minimum tensile strength of steel shall be 30 ± 1 tons per square inch, or for that matter $30\,^{-0}_{+1}$ tons per square inch. It may be noted that a single value statement of 29, 30 or 31 tons per square inch as the minimum strength, depending on the actual need of the situation, will be much more appropriate and unambiguous, for it will cover the full significance of the requirement.

For the purpose of conversion of maximum and minimum single number values from one system of units to another, it is important to determine beforehand whether the number of significant figures appearing in the stated value adequately expresses its precision or whether the method of measurement expected to be employed or the character of requirement intended to be imposed would normally require additional significant figures to be added to the value to achieve the requisite degree of precision in the stated value. If such be the case, an additional zero or zeros may be added to the stated value and considered significant for the purpose of conversion (*see also* Notes under **2.2**). For example, the 30 tons per square inch as minimum tensile strength may imply an accuracy of only ±0·5 ton per square inch, if a very coarse determination was involved, in which case the two significant figures of 30 would suffice for conversion. But such a position will be exceptional since it is customary to measure tensile strength of metals of this order of magnitude to a greater degree of precision and, in most cases, tensile strength specifications require compliance to a specified value to a larger number of significant figures. The usual practice is to determine tensile strength of this order to the nearest 100 lb or the nearest hundredweight. Thus, the original value of 30 tons for the purpose of conversion may be taken to mean 30·0 tons per square inch, with an understanding that its precision is of the order of ±0·05 ton per square inch.

4.3.2.1 In all Indian Standard Specifications, a general practice has been adopted to include in their Forewords the following paragraph:

> "For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with *IS : 2-1949. The number of places retained in the rounded off value should be the same as that of the specified value in the standard."

The intention of this paragraph is that the precision of values such as those discussed under **4.3.1** and **4.3.2** shall be automatically implied in the stated values in Indian Standard Specification. In respect of all such values specified in Indian Standards carrying the above quoted paragraph in the Foreword, there is, therefore, no need to give any special thought to their possible or probable precision, since they have originally been stated with a view to comparing them with the test results after the latter have been rounded off. Thus, their precision is implied to be ±0·5 of the unit in the last significant figure.

4.3.3 *Multiple Number. Values Including Statement of Precision*, such as tolerance limits or errors of determination, include most precision dimensions on engineering drawings, specification values requiring close inspection limits, results of accurate measurements, etc.

The precision of such values may be stated in any of the ways illustrated by the following examples:

a) Weight of cloth shall be 12·2 to 12·8 oz per square yard,

b) Grind the plug to $1{\cdot}2\,^{+0{\cdot}000\,07}_{-0{\cdot}000\,56}$ in diameter,

c) Internal diameter of the collar shall be $1\frac{3}{8}\,^{+0{\cdot}003}_{-0{\cdot}000\,2}$ in,

d) Distance between centres of two holes shall be $1\frac{3}{4}$ ±0·015 in,

e) Acceleration due to gravity as determined in the experiments was 32·191 05 ± 0·000 02 ft per second per second, and

f) Weigh about 1 g of the composite sample accurately to 0·1 mg.

In each of these examples while the precision and, therefore, the limits of variation of the main value have been explicitly stated, the precision of the related tolerances or associated error of errors themselves is not apparent in each case. The precision of the tolerances or the variation of limits determines the interchangeability of parts and depends on the method of measurement employed or intended to be employed in manufacture and inspection[*]. It is important, therefore, that the precision of the tolerance limits be assessed before conversion of such values is attempted.

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*Since revised.

4.3.3.1 A brief discussion of the above examples will illustrate the type of decisions that may have to be made before conversion of such values is attempted:

a) *Weight of cloth* 12·2 *to* 12·8 *oz per sq yd*— The accuracy of the method of measurement in this case depends on both the measurement of area and that of weight. It may be reasonably assumed that the accuracy of 0·05 oz per sq yd implied in the statement of this value is adequate, yet the usual method of measurement involved may be able to give a better accuracy. In certain cases, it may be desirable to investigate the question to ascertain the limiting accuracy of such values by referring to appropriate standard method of test such as the Indian Standards on the subject. In this particular case, a reference may be made to [†]IS : 242-1951 Method for the Determination of Weight per Square Yard (or Square Metre) and Weight per Linear Yard (or Linear Metre) of Cotton Fabrics, together with the associated standard [‡]IS : 241-1951 Method for the Determination of Cotton Fabric Dimensions. From these standards it will be seen that weight measurement is required to be accurate to 1 in 500 or, say, to 0·2 percent and the length measurement to ±0·5 in, and width to $\pm\frac{1}{16}$ in. The two latter figures when applied to a minimum size of piece of, say, 10 yd × $\frac{3}{4}$ yd lead to a maximum error of about 0·4 percent in area determination. Thus, the weight per unit area result is likely to be uncertain up to 0·2 + 0·4 or 0·6 percent. In case of our example, this implies an error of about ±0·08 oz per sq yd, which is of the same order of magnitude as the usual presumption of one-half unit of the last significant figure, namely ±0·05. In such a case, the 12·2 to 12·8 value may, therefore, be used as such for conversion with an implied accuracy of ±0·05.

In other cases, it is quite likely, particularly where practice followed in Indian Standards is not followed, that in specifying the original value account has not been taken of a higher degree of precision attainable in measurement. In such cases, it will be justified to rewrite the value to more than the given number of significant figures, before conversion is attempted. Thus, in the above example suppose the estimated error of determination had come out to be ±0·01 oz per sq yd instead of 0·08, then the original value should be rewritten as " 12·20 to 12·80 " for the purpose of conversion.

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[*] For more detailed discussion on this subject, reference is invited to :

ADAMS, G. C. Principles and Practice Governing Interchangeability and Specification of Manufacturing Limits of Size, as Influenced by Statistical Considerations. *Proc.* (*A*) *Inst. Mech. Eng.*, Vol. 167 No. 2, pp. 154-169 (1953).

[†] Superseded by IS : 1964-1970 Methods for determination of weight per square metre and weight per linear metre of fabrics (*first revision*).

[‡] Superseded by IS : 1954-1969 Methods for determination of length and width of fabrics (*first revision*).

b) Plug Diameter: $1{\cdot}2\ ^{+0{\cdot}000\,07}_{-0{\cdot}000\,56}$ in

c) Collar Diameter: $1\tfrac{3}{8}\ ^{+0{\cdot}003}_{-0{\cdot}000\,2}$ in

d) Hole Distance: $1\tfrac{3}{4}$ ±0·015 in

These three cases may be dealt with together for they are all concerned with precision dimensions intended to ensure interchangeability of parts. In practice it is possible to confirm to such tolerance limits only within the accuracy of the method of dimensional inspection adopted, whether by limit gauging or by direct measurement. The highest precision to which best tool-room practice may extend in India would be about 0·000 05 in or 0·001 mm (1 micron). In normal engineering practice, for tolerances of 0·001 in or coarser, accuracy of measurement to ensure interchangeability may be taken to be ± 4 percent, and for tolerances finer than 0·001 it may be taken to be 0·000 03 in uniformly. In terms of metric units this means an accuracy of ± 4 percent for tolerances of 0·025 mm or coarser and ±0·000 8 mm for tolerances finer than 0·025 mm (*see* **0.4**).

For the purpose of this Standard Guide it is recommended that the precision of a stated tolerance may be taken to be ±5 percent for tolerances 0·001 in or coarser and ±0·000 05 in for tolerances finer than 0·001 in. *Thus in rewriting tolerance limits for inch dimension for conversion purposes, it will suffice to add one zero to all tolerances of any magnitude having one significant figure, provided no zero is added beyond the fifth place of decimal fraction in inches. This procedure also implies that the converted values need not be rounded to a fineness closer than* 0·000 05 *in or* 0·001 *mm. Similarly for rewriting millimetre dimensions for conversion, one significant zero may be added to all one significant figure limits, provided no zero is added beyond the third place of decimals.* No change need be made in rewriting tolerance limit values of 2 or more significant figures whether they are in inches or millimetres.

Thus, for the purpose of conversion, values typified by the dimensions in the examples given under (b), (c) and (d) should be rewritten so that the number of decimal places in both the main dimensions and in the tolerances are the same thus:

b) Plug Diameter: $1{\cdot}200\,00\ ^{+0{\cdot}000\,07}_{-0{\cdot}000\,56}$ in

c) collar Diameter: $1.375\ 00^{+0.003\ 00}_{-0.000\ 20}$ in

d) Hole Distance: **1·750** **±0·015** in

In applying this rule to vulgar fractions, it **may** be noted that the number of decimal places to be retained in the decimal version of fractions will be the same as that in the tolerance limit rewritten to include the implication of its accuracy.

For example:

i) **$1\frac{7}{32}$ ± 0·002** in shall be rewritten as **1·218** 8 **±0·002** 0 in though actually **$1\frac{7}{32}$ = 1·218** 75,

ii) **$\frac{37}{64}$ ±0·01** in shall be rewritten as **0·578 ±0·010** in though actually **$\frac{37}{64}$ = 0·578** 125.

Here again, as elsewhere, *IS : 2-1949 shall be followed for rounding off purposes.

e) ***Acceleration due*** to ***gravity*:** 32.19105 **±0·000 02** ***ft per sec per sec* — As** already stated elsewhere, it is quite safe to convert values like this expressing experimental results just as they stand, for the precision of both the main value and the error may each be. taken to be adequately included in the statement.

f) ***Weigh about* 1 *g accurately to* 0·1 *mg* —** The result of such weighing may, for instance, be 1 **·013** 5 g whose accuracy may be taken to be **±0·000** 1 g. This example is of the nature of an **experimental** result and may be treated as (t) above.

4.3.3.2 In order ***to*** avoid errors of addition and subtraction, which in some cases are likely to be aggravated in conversion, it is further proposed that before converting multiple number values including statement of precision, the main values and the tolerances (or errors) be expressed as limiting values. Thus, the examples discussed under 433.1 may be rewritten **as** follows before actual conversion is made:

a) 12.2 to **12·8 oz** per **sq** yd
b) **1·200** 07 and **1·199** 44 in
c) **1·378** 00 and **1·374** 80 in
d) 1.765 and 1.735 in
i) **1·220 8** and 1.2168 in
ii) **0·588** and **0·568** in
e) 32.19107 and 32.19103 **ft** per **sec** per **sec**
f) **1·013** 6 and **1·013** 4 **g**

Since it is generally preferred to use the limiting values as such far workshop practice, the converted dimensional values may be left in the

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***Since revised.**

form of limiting values. But, if tolerances or errors of converted values in terms of new units of measurements are desired, they may be derived from the converted limiting values by simple subtraction and the results expressed accordingly.

4.4 **Dimensional Designation** Values are really not values in the strictest sense of the word but merely labels which designate the type, class or category of objects, articles or materials. Such designations may be divided into two sub-categories, namely (a) the Standardized Dimensional Designations, and (b) the Non-Standard (or *ad hoc)* Dimensional Designations.

4.4.1 *Standardized Dimensional Designations* are those which are recognized in current standards and are employed in common usage.

Designation values normally correspond to one of the dimensions of the article or object designated, but the article or object is not necessarily completely defined by it; it may require several additional dimensions and attributes to define the article fully. In certain cases, standard dimensional designation does not represent any dimension of the article or object it designates. In most cases, the designation dimension corresponds only nominally to one of the actual dimensions.

Examples:

a) 8 x 4 *in Standard I-beam* has a depth of 8 in and a flange width, of 4 in, but to define it completely the thickness of its web and flange and sometimes also the slope of the flange are to be specified. If, in addition to the shape of its cross-section, one is interested in the material, it will be required to indicate whether it is of ordinary structural steel, high tensile steel *or* something else.

b) 6 *in-lift ring bobbin* has none of its dimensions corresponding to anywhere near 6 in. Here the significance of 6 in is that the ring spinning machine on which the bobbin is used has a lift of 6 in and, therefore, the yarn wound on the bobbin is spread over it to that extent.

c) *2 in welded steel pipe* has neither the inside nor the outside diameter equal to 2 in, though they are both close to it. In this class of pipes, while the outside diameter for a given size designation may be fixed, the inside diameter may vary depending on the wall-thickness for which severalchoices are available.

d) 16 *in table-type electric fan* has a blade sweep of 16 in, but its service, characteristics in terms of air-delivery, energy-consumption, safe speed, etc, are the really useful attributes which define it more logically (see *IS : 555-1955 Specification for Table-Type Electric Fans).

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*Second revision in 1967

e) *IS Sieve* 30 indicates the Indian Standard Sieve having openings approximating to 30 × 10 or 300 microns, although the exact size of openings is required to be 296 microns within specified tolerances (*see* *IS : 460-1953 Specification for Test Sieves). The British practice of specifying sieves is in terms of so many openings per inch length, thus a 52-mesh British Standard Sieve which corresponds approximately to IS Sieve 30 is intended to have 52 openings per linear inch both weft-ways and warp-ways. But the number 52 by itself is not at all indicative of the operating dimension of the sieve, namely the opening, because the wire diameter has to be known before the opening can be calculated.

f) 18-8 *Chrome-nickel steel* designates the variety of stainless steel containing 18 percent of chromium and 8 percent of nickel within specified tolerances. Its exact chemical composition and state of heat-treatment, however, have to be specified for a fuller description.

4.4.1.1 It is obvious that such designations, if left alone in the original form, cannot interfere with engineering operations such as are normally involved in design and construction of machines and structures, nor can such practice lead to misunderstanding or incomplete comprehension. Actually, as long as the article or object continues to be manufactured in conformity with prevailing standards, the retention of the current designations will help to avoid confusion. The specific dimensions defining the article or object in detail, however, may require to be converted for certain purposes.

When a current system of units of measurement in a given industry, trade or nation undergoes a change, it is to be expected that, during the changeover period, standardization authorities concerned will formulate standards for articles and objects in which the governing dimensions which give rise to the designation of the objects will also be standardized in metric units. When such standardization is carried out, it should be possible to decide what new designations should be devised. Such new designations may be in the new set of units or may be entirely free from any unit of measurement. For example, as long as the present 8 in × 4 in I-beams and ½ in flats are produced in the country, there should be no objection to the statement: " Cut off a 5·71 metre length of an 8 in × 4 in I-beam and strengthen it by the addition of 2 flats, ½ in × 4 in and 5·50 metres long to the flanges ". In case, in the future, standardization of production in steel is enforced in metric units, the corresponding statement may be: " Cut off a 5·71 metre length of a 200 × 100 mm I-beam and strengthen it by adding two flats, 15 mm × 100 mm and 5·50 metres long to the flanges ".

4.4.2 *Non-standard Dimensional Designations* are those which are used in engineering practice or trade for convenience of operations within limited spheres of a company, factory or workshop, but they are not covered by national or international standards nor are they found in general use.

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*Since revised.

For example:

a) 8 *in aluminium circles* intended for utensil manufacture designates a size of blanks among several sizes prepared in a factory for further processing.

b) 12 × 9 *ft Mirzapur carpet* is one size of carpets among several available in trade, but normally there is no hard and fast rule to limit the choice of carpet sizes [*see* *IS : 433-1953 Specification for Handloom Carpets (Mirzapur) for Export].

c) ⅛ *in steel shot* for use in tumbling operations in a. foundry.

d) 2 in *blanks* for further machining.

4.4.2.1 It is advisable that non-standard designations of this type should be converted to the new set of units when associated dimensions are being convcrtai. In doing so, it is desirable to consider how far they may be rounded off to a convenient number. This is an individual problem to be decided by the company or the management of the factory concerned. For example, an 8 in aluminium circle may be converted as 20 cm circle or it may be necessary to keep it at 20·3 cm (or even 20·32 cm) depending entirely on the requirements of further processing. Similarly, trade considerations will dictate whether a 12 x 9 ft carpet be redesignated as 4 × 3 metres or 3·7 x 2·7 metres or 9 square metres or simply size x, or y, or z. Sii remarks apply to examples (c) and (d) under **4.4.2**.

In cases where additional information is not available or job requirements are indeterminate to guide conversion, the non-standard designations may be treated as unqualified single number values discussed under **4.3.1**.

4.4.3 It must be recognized that occasions may arise where the distinct& between the standardized and non-standard dimensional designations may not be clear-cut or self-evident. In such cases, it may be useful to study the problem in some detail before deciding the issue whethatoconvcrtornotto convert, and, if it is decided to convert, how far to round off.

4.5 **Monetary Values** include simple values involving amounts of money expressed simply in tams of rupees, annas and pier, and complex values involving prices, rates, tariffs, wages, duties, discounts, interest, taxes, etc, in which monetary quantities arc liikcd with some other units of measure.

Under the Indian Coii (Amendment) Act, 1955, the Indian rupee is to be divided into 100 '*Paise*'. Thus the annas and pies in the original given valua will need be converted to decimalized form involving new currency units of rupees and '*Paise*'.

Ordinarily, it should be possible to treat all monetary values in the same manner as the inexact values discussed under 4.3 and particularly 43.1. But since the smallest monetary unit is one '*Paisa*' or Re 0·01, the fineness of rounding for the converted value has necessarily to be chosen with due regard to the practical consideration that no monetary transaction or actual exchange of money can take place in terms of a smaller fraction than one '*Paisa*'. But that is not to say that a fineness of rounding finer than 0·01 of a rupee will never be required; this will be seen from the discussion under **4.5.2** dealing with complex monetary values.

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*Since superseded by IS : 2231-1962 Method of grading hand-made wool carpets. (Since revised).

4.5.1 *Simple Monetary Values* are simple statements of amounts of money without any linkage with another unit of measure.

For example:

a) Gratuity due to A is Rs 400/8.

b) B owes C a sum of Rs 45/4.

c) Aggregate value of shares owned by D including the 7 percent dividend due next month amounts to Rs 359/8/3.

d) E's contribution was Rs 1001.

Conversion of simple monetary values involves decimalization of the given values and rounding off the decimalized values to a fineness of 0·01 of a rupee or, say, to two places of decimal. It is natural that some of the converted values will not require any roundii off because they may lead to exact decimalized fractions involving only two or even less places of decimal, but all of these should be carried to two places for the sake of clarity of expression.

For example:

Given Value	*Decimalized Value*	*Converted Value*
Rs 400/8	400·5	Rs 400·50
Rs 45/4	45·25	Rs 45·25
Rs 359/8/3	359·515 625	Rs 35952
Rs 1 001/-	1 001	Rs 1 001·00

4.5.2 *Complex Monetary Values* involve more than a simple statement of an amount of money; they are in the nature of a rate, that is an amount of money associated with some other unit of measurement.

For example:

a) Price of oranges	Re -/8/- a dozen
b) Daily wages	Rs 10/8/2 per day
c) Discount rate	Re -/3/6 per rupee
d) Rate of interest	Rs 5/6/- percent
e) Rental	Rs 39/3/4 per acre
f) Sales tax on cloth	Re -/2/- per 100 yards
g) Road freight	Re -/-/4 per mile
h) Import duty	Rs 10/-/- per maund

It will be seen that the above examples of complex monetary values may be broadly divided into two'general categories. The first four examples represent values linked with units of measure, such as numbers, time, currency, and percentage which latter in themselves do-not require any conversion. The last four examples on the other hand are linked with non-metric units of measure, such as acre, yard, milt and maund, which may need be converted to metric units. Thus in the first category of such values only the decimalization of currency is rquired and in the latter category, besides decimalization of currency, conversion in terms of the associated unit in the given values to a new set of physical units is also required. In both of these cases, however, the choice of fineness of rounding is a complex matter and not as simple as in the case of simple monetary values discussed under **4.5.1**.

The choice of fineness in these cases is complicated, because a complex value represents a rate which is used as a basis for calculating the amount of money that may have to change hands, and it is this final amount which is capable of being rounded off to the nearest one '*Paisa*' or 0·01 of a rupee. Thus-he choice of fineness will depend on the particular application in connection with which the rate represented by the given complex value is to be used. If a rate is normally to be used for division, for instance a rate per ton used for determining price of a few pounds, then the fineness of rounding can be the same as in case of simple monetary values (*see* **4.5.1**), namely one '*Paisa*'. On the other hand if multiplication is involved in determining total amounts on the basis of a given rate, then the fineness of rounding off the converted'rate will depend on two considerations:

a) the magnitude of the maximum multiplier that may be envisaged, and

h) the minimum monetary unit to which the final payment need be rounded off.

4.5.2.1 An excellent example illustrating these considerations is furnished by railway fare rates. The rate itself may be stated in terms of pies or annas per mile and made applicable to a transport system the maximum haulage distance of which is known. Further, the fares between given points may be rounded off to one anna after being calculated for each pair of stations involved. In case of air fares the rounding off may be to the nearest rupee. It is thus clear that the fineness of rounding of the converted fare rates could be determined, if the maximum distance to which the fare rate is to be made applicable is known and a decision is taken as to the minimum monetary unit to which fmal fares will be rounded off. More specifically, consider the following example:

Given:

Fare rate	= 3 pies per mile
Maximum distance involved	= 1 260 miles

Minimum monetary unit for rounding off the point-to-point fares

Present	= 1 anna
Future	= 5 '*Paise*'

Solution:

3 pies per mile
= Re 0·015 625 per mile.
= Re 0·015 625 x 0·621 371 per kilometre
= Re 0·009 706 266 per kilometre

1260 miles
= 1 260 × 1·609 kilometres
= 2 000 kilometres approx

Re 0·05 ÷ 2 000
= Re 0·000 025
∴ fineness of rounding
= Re 0·000 01
∴ converted fare rate
= Re 0·009 71 per kilometre

4.5.2.2 It must, however, always be borne in mind that it may not always be necessary to be absolutely exact in converting a rate, because there are so many factors that go to determine a given rate and many of these factors are constantly being affected by economic and other considerations. There is thw nothing in the nature of a mathematical exactitude in any of the market rates which fluctuate all the time. Once they begin to be quoted in terms of new currency and new units of measurement, no conversion problem need arise. Even in case of tariffs and fares, slight adjustments are always possible. For instance, if in the numerical example given under **4.5.2.1** the converted fare rate was rounded off to second place of decimal instead of the fifth, i.e., Re 0·01 per kilometre, it would mean over-charging the traveller something less than 3 percent of what he may be paying before conversion. Administration concerned may find that this amount may be considered justified because of some new facility recently made available to travellers, but which, if required to be charged for under ordinary conditions, would involve an unjustifiable amount of readjustment in the fares.

Thus it is clear that in converting complex monetary values, each should be individually examined for the purpose of determining the appropriate fineness of rounding off the converted vahu.

5. PROCEDURE FOR CONVERSION

5.0 It has been clearly brought out by the discussion under 4 that the significance of values as used in engineering and trade practices depends on the context in which they are used and the purpose they are intended to serve. The mode of usage and the manner of expression of a given value determine, to a large extent, the associated accuracy of the values which must be carried over to the converted value. Even where tolerance limits of a specified value are stated, it is essential that in order to ensure interchangeability of parts made to such tolerances, careful consideration be given during conversion to the associated accuracy of the tolerances themselves, which accuracy in turn depends upon design requirements and the manufacturing precision and inspection techniques employed in production.

It is important, therefore, that instructions given under 4 should be carefully studied before the rules for conversion given under 5.1 and 5.2 are used for actual conversion. In Appendix B are summarized the conclusions of this discussion to assist in rewriting given values before conversion.

5.0.1 To facilitate the statement of the rules, monetary values of category V (*see* 4.5) have been separately dealt with under 5.2, while values of categories I to IV (set 4.1 to 4.4) are covered under 5.1.

5.1 **Rules** — Keeping in mind the precaution discussed under 5.1.2, the rules to be followed in the conversion of given values of categories I, II, III and IV from one set of units to another shall be as follows:

Rule I- Classify the given value according to categories discussed under 4 and examine its significance in the light of the discussion under appropriate category.

Rule II — Rewrite the value, modifying it, if necessary, as directed under 4 (see *also* Appendix B).

Rule III — Choose an appropriate conversion factor from those *given* under 3 and in Appendix A, and round it off, if need be, to appropriate number of decimal places for the particular conversion in hand. It is generally adequate to retain in the conversion factor two more significant figures than those appearing in the rewritten given number.

NOTE — To convert a value expressed in derived units, do not use more than one conversion factor in repeated operations, but select such a derived conversion factor from among those given as will require only one arithmetical operation, preferably multiplication. If such a factor is not readily available. it may be calculated by using the principal conversion factors or other factors from the given list.

This procedure is recommended to reduce the chance of avoidable error and to save time in calculations.

For example:

A pressure value given in tons per sq in should *not* be converted by first multiplying by 1016·05 to convert it to kg per sq in and then dividing by 645·16 to obtain kg per sq mm. Instead, according to this rule, the converted value should be obtained directly by using the factor.

1 ton per sq in = 1·574 9 kg per sq mm.

Similarly, to convert an area value given in square inches into square centimetres, multiply directly by 6451 6 and not by 2·54 twice.

Rule IV — Convert the rewritten value by using the selected or calculated conversion factor and carry out the conversion to at least two more significant figures than in the rewritten value.

Rule V — For rounding off the converted value, decide the fineness of rounding as follows:

a) Write down the significant part of the rewritten original value for using it as standard of comparison. Call it S_0.

b) Write down the significant part of the converted value and drop from it one figure at a time until the significant part assumes for the first time the same order of magnitude as S_0. Call this S_1.

c) Drop another significant figure from S_1 and observe that the resultant value S_2 also has the same order of magnitude as S_0.

d) Of S_1 and S_2, choose one as S which bears the least ratio to S_0. That is

$$\text{if } \frac{S_1}{S_0} \leqslant \frac{S_0}{S_2}, \text{ choose } S_1 \text{ as } S$$

$$\text{if } \frac{S_1}{S_0} > \frac{S_0}{S_2}, \text{ choose } S_2 \text{ as } S$$

If S_1 contains only one significant figure, obviously S_1 shall be taken to be S.

e) The fineness of rounding should then be taken as unity in the last place retained in S.

To ensure interchangeability of machined parts, the fineness of-rounding for linear dimensions need not be finer than 0.001 mm or 0·000 05 in (*see* 4.3.3).

Rule VI — Using the fineness of rounding thus determined, round off the calculated converted value and retain in the final converted value all the significant zeros and drop from it all the non-significant zeros.

NOTE — In case of Multiple Number Values including statement of precision, the tolerances of errors in terms of new units of measurement may be obtained, if desired, from the converted limiting values.

5.1.1 *Examples* — A few examples of the application of Rules of Conversion specified under 5.1 are given in Table III in which the procedure of conversion is also illustrated.

5.1.2 *Precaution* — The rules given under 5.1 have been designed to ensure that the accuracy of statement or the significance of a given value is reflected in the converted value as closely as possible within limitations imposed by the operation of conversion. It will be seen from Table II that an unqualified single significant figure value is subject to an error of 5·6 to 50 percent and a two significant figure value from 0·5 to 5 percent and so on. Thus, on conversion, one and two significant figure values are likely to be subject to errors of similar orders of magnitude. But then, if such original values are rewritten in the light of context and the number of significant figures in their restatement is increased to the extent justified by circumstances of the case, then the converted values would automatically reflect the order of accuracy desired to be expressed.

For example, a linear density of 1 lb per ft converted as such into metric units, according to the above'rules, would lead to an answer of 1 kg per metre. The conversion factor being 1·488, one may well say that the error of conversion is 48·8 percent in this case. It may be noted that the error of statement of the original value as it stands is actually 50 percent (*see also* 4.3.1.4 and Table II) and, therefore, the error of 48·8 percent in the converted value is not greater than that of the original value.

Now, if in the light of context, we could rewrite the given value as 1·0 lb per foot, the converted value according to the above rules would be 1·5 kg per metre. The accuracy of statement of the original value is thus enhanced to 5 percent and that of the resulting value to better than one percent (see *also* example 11 in Table III).

5.2 **Monetary Values** — With due reference to the significance of the two categories of monetary values discussed under 4.5, the rules to be followed for their conversion shall be as follows:

Rule VII — For simple monetary values, decimalize the given value and round off or carry to two decimal places in terms of rupees (or to one '*Paisa*').

Rule VIII — For complex monetary values, decimalize the given value and convert it 'in respect of the associated unit of measurement, if necessary. For rounding off, determine the appropriate fineness of rounding in relation to the use to which the converted value is to be put.

NOTE — In selecting a suitable conversion factor for use in converting monetary values associated with convertible units of measurement, do not select a factor which involves either a multiple operation (*see* Note under Rule III, in 5.1) or one which involves a division. The reciprocal conversion factors given in the last columns of both Tables I and IV are the appropriate factors for this purpose, which should be used.

For example:

To convert the value Rs 11/8/- per square yard, *do not use* either of the following factors (Table IV)

1 yard = 0·914 4 metre
1 metre = 1·093 61 yards
1 square yard = 0·836 127 square metre,

because the first of these requires double division, the second double multiplication, and the third a division. The most convenient and appropriate conversion factor for this purpose is

1 square metre = 1·195 99 square yards,

given under the reciprocals column of Table IV, which involves only one multiplication operation.

For further illustrative examples, reference is invited to 4.5.2.

TABLE III TYPICAL EXAMPLES OF CONVERSION OF CERTAIN VALUES INDICATING PROCEDURE RECOMMENDED IN THIS GUIDE

(*Clause* 5.1.1)

Sl No.	Given Value		Conversion Factor	Calculated Converted Value	Significant Part of		Fineness of Rounding	Final Converted Value	(See Note)
	Original	Rewritten			Rewritten Value	Converted Value			
1	$4\frac{1}{2}$ in	4·5 in	25·4 mm/in	114·30	45	11 4~~30~~	1	114 mm	
2	$4\frac{1}{2}$ ± 0·001 in	4·501 0 4·499 0	25·4 mm/in	114·325 40 114·274 60	45 010 44 990	11 432 5~~40~~ 11 427 4~~60~~	0·001	114·325 114·275 mm	
3	1·2 ± 0·000 5 in	1·200 50 1·199 50	25·4 mm/in	30·492 700 30·467 300	120 050 119 950	30 492 ~~700~~ 30 467 ~~300~~	0·001	30·493 30·467 mm	1
4	$1\frac{3}{8}$ ± 0·01 in	1·385 1·365	25·4 mm/in	35·179 0 34·671 0	1 385 1 365	351 7~~90~~ 346 7~~10~~	0·01	35·18 34·67 mm	
5	$1\frac{7}{32}$ ± 0·001 in	1·219 8 1·217 8	25·4 mm/in	30·982 92 30·932 12	12 198 12 178	3 098 2~~92~~ 3 093 212	0·001	30·983 30·932 mm	
6	32·191 05 ± 0·000 02 ft	32·191 07 32·191 03	30·48 cm/ft	981·183 813 6 981·182 594 4	3 219 107 3 219 103	9 811 838 ~~136~~ 9 811 825 ~~944~~	0·000 1	981·183 2 ±0·000 6 cm	
7	17 miles 3 furlongs	17·375 miles	1·609 34 km/miles	27·962 28	17 375	2 796 2~~28~~	0·001	27·962 km	2
8	31 tons per sq in	31 tons per sq in 31·00	1·574 88 kg per sq mm/tons per sq in	48·821 28	31 3 100	4 8~~82 128~~ 4 882 ~~128~~	1 0·01	49 kg/sq mm 48·82 kg/sq mm	3
9	12·2 to 12·8 oz/sq yd	12·2 oz/sq yd 12·8	33·906 g per sq m/oz per sq yd	413·653 433·997	122 128	41~~3 653~~ 43~~3 997~~	10	4·1 × 10^2 to 4·3 × 10^2 g/sq m	
10	537 US gallons	537 US gal	3·785 3 l/US gal	2 032·706	537	2 03~~2 706~~	10	20·3 × 10^2 litres	
11	4 Imperial gallons	4 Imp gal 4·0	4·546 l/Imp gal	18·184	4 40	1~~8 184~~ 18 ~~184~~	10 1	20 litres 18 litres	4
12	15 seers 5 chhataks	15·31 seers	0·933 104 kg/seer	14·285 8	1 531	142 8~~58~~	0·01	14·29 kg	
13	5 tolas 7 annas	5·44 tolas	11·664 g/tola	63·452 16	544	6 34~~5 216~~	0·1	63·5 g	5
14	13 acres	13 acres 13·00	0·404 686 hectare/acre	5·260 92	13 1 300	52~~6 092~~ 526 ~~092~~	1 0·01	5 hectares 5·26 hectares	4

NOTE 1 — In this example, the fineness of rounding off the converted value, judging from its significant part according to Rule V should be 0·000 1 mm. But to ensure interchangeability of machine parts the fineness of rounding need not be finer than 0·001 mm according to Rule V.

NOTE 2 — Here it will be noted that in the absence of information the precision of the given value has been assumed to be ±0·000 5 miles, or say about 2·5 ft. Reference is invited to discussion of this point under **4.3.1.1**, example (b).

NOTE 3 — In these examples, two separate rewritten values have been converted to illustrate how the difference in precision influences the various steps in conversion. As stated elsewhere, the choice of precision for rewriting will depend upon the context in which the value is stated.

NOTE 4 — This is another example illustrating the need for exercising the precaution discussed under **5.1.2**, that, when converting a single significant figure value, it is necessary first to rewrite it to an appropriate degree of accuracy of statement.

NOTE 5 — 1 tola = 16 annas is a recognized fraction under The Standards of Weight Act 1939 (Act IX of 1939).

APPENDIX A

(*Clauses 3.2 and 5.1*)

TABLE IV DERIVED CONVERSION FACTORS AND COMMONLY USED UNITS

Conversion factors are given correct to five or six significant figures depending on the magnitude of the figure. More significant figures have been specified in the case of exact values and those internationally accepted. For complete set of conversion tables refer to IS : 786-1956.

NON-METRIC UNIT	METRIC EQUIVALENT		RECIPROCAL	
Length				
1 inch	25·4	millimetres (exact)	0·039 370 1	in/mm
1 foot	30·48	centimetres (exact)	0·032 808 4	ft/cm
1 yard	0.914 4	metres (exact)	1·093 61	yd/m
1 furlong	201·168	metres (exact)	0·004 970 97	furlong/m
1 mile	1·609 344	kilometres (exact)	0·621 37	mile/km
Area				
1 square inch	6·451 6	sq centimetres (exact)	0·155 000	sq in/sq cm
1 square foot	929.030 4	sq centimetres (exact)	0·001 076 39	sq ft/sq cm
1 square yard	0·836 127 36	sq metres (exact)	1·195 99	sq yd/sq m
1 acre	4 046·86	sq metres	0·000 247 105	acre/sq m
,,	40·468 6	acres	0·024 710 5	acre/are
,,	0·404 686	hectares	2·471 05	acre/hectare
1 square mile	258·999	hectares	0·003 861 02	sq mile/hectare
,, ,,	2·589 99	sq kilometres	0·386 102	sq mile/sq km
Cubic Measure and Capacity				
1 cubic inch	16·387 1	cu centimetres	0·061 024	cu in/cu cm
1 cubic foot	0·028 316 8	cu metres	35.314 71	cu ft/cu m
1 cubic yard	0·764 55	cu metres	1·307 95	cu yd/cu m
1 Imperial gallon	4·545 96	litres	0·219 976	Imp gal/litre
1 US gallon	3·785 29	litres	0·264 180	US gal/litre
Weight				
1 ounce (avoirdupois)	28·349 5	grams	0·035 274 0	oz/g
1 pound (avoirdupois)	0·453 592 4	kilograms	2·204 622	lb/kg
1 hundredweight	50·802	kilograms	0·019 684 1	cwt/kg
1 ton (2 240 lb avoirdupois)	1·016 05	metric tons	0.984 21	ton/metric ton
1 pound (apothecary or troy)	0·373 242	kilograms	2.679 23	lb (ap or troy)/kg
1 grain	0·064 799	grams	15·432 4	gr/g
1 tola	11·663 8	grams	0·085 735	tola/g
1 seer	0·933 10	kilograms	1·071 69	sr/kg
1 maund	37.324 2	kilograms	0·026 792 3	md/kg

(*Continued*)

TABLE IV DERIVED CONVERSION FACTORS AND COMMONLY USED UNITS — *Contd*

	Non-Metric Unit	Metric Equivalent		Reciprocal	
	Density and Concentration				
1	ounce per cubic inch	1·729 99	grams per cu centimetres	0·578 04	oz per cu in/g per cu cm
1	pound per cubic foot	16·018 5	kilograms per cu metre	0·062 428	lb per cu ft/kg per cu m
1	ton per cu yard	0·001 328 98	metric ton per litre	752·46	ton per cu yd/metric ton per litre
1	ounce (avoirdupois) per gallon (Imp)	6·236 2	grams per litre	0·160 354	oz per gal (Imp)/g per litre
1	pound (avoirdupois) per gallon (Imp)	99·779	grams per litre	0·010 022 1	lb per gal (Imp)/g per litre
	***Linear Density**				
1	ounce per foot	0·930 10	grams per centimetre	1·075 15	oz per ft/g per cm
1	pound per foot	14·881 6	grams per centimetre	0·067 197	lb per ft/g per cm
1	pound per yard	4·960 55	grams per centimetre	0·201 597	lb per yd/g per cm
1	pound per mile	0·281 849	kilograms per kilometre	3·548 00	lb per mile/kg per km
	Pressure, Stress and Area Density				
1	pound per square inch	70·307	grams per sq centimetre	0·014 223 3	lb per sq in/g per sq cm
1	pound per square foot	4·882 43	kilograms per sq metre	0·204 816	lb per sq ft/kg per sq m
1	ton per square inch	0·157 488	metric ton per sq centimetre	6·349 7	ton per sq in/metric ton per sq cm
1	ounce per square yard	33·905 8	grams per sq metre	0·029 493 5	oz per sq yd/g per sq m
1	†normal atmosphere (14·695 9 pound per square inch)	10·332 2	grams per sq millimetre	0·096 784	normal atmosphere/g per sq mm
	Work, Energy and Heat				
1	foot-pound	0·138 255	kilogram metres	7·233 0	ft-lb/kg metre
1	British thermal unit	0·251 996	kilocalories	3·968 32	Btu/kilocalorie
1	foot-pound	0·376 6	‡milliwatt hours	2·655	ft-lb/milliwatt hour
	Power				
1	foot-pound per second	0·138 255	kilogram metre per second	7·233 0	ft-lb per sec/kg metre per sec
	”	1·355 82	‡watts	0·737 56	ft-lb per sec/watt
1	horse power (550 foot-pound per second)	76·040	kilogram metre per second	0·013 150 9	horse power/kg m per sec
	” ”	0·745 70	‡kilowatts	1·341 02	horse power/kilowatt

*Linear density units for textile yarns in both direct and indirect systems are dealt with in IS : 234-1952 Methods for Determination of Mean Fibre Weight per Unit Length (Cotton) and IS : 237-1951 Method for Determination of Cotton Yarn Count (or Yarn Melidity in tex). Melidity is a term recently introduced in textile industry standards to denote linear density of yarn or fibre in direct systems of measurement. The latest internationally recommended unit for melidity measurement is the tex, which is equal to one gram per kilometre. To inter-convert yarn count and melidity in tex, use the formula : Count × Melidity = 590·541, where count is the number of hanks (840 yd) of yarn per pound.

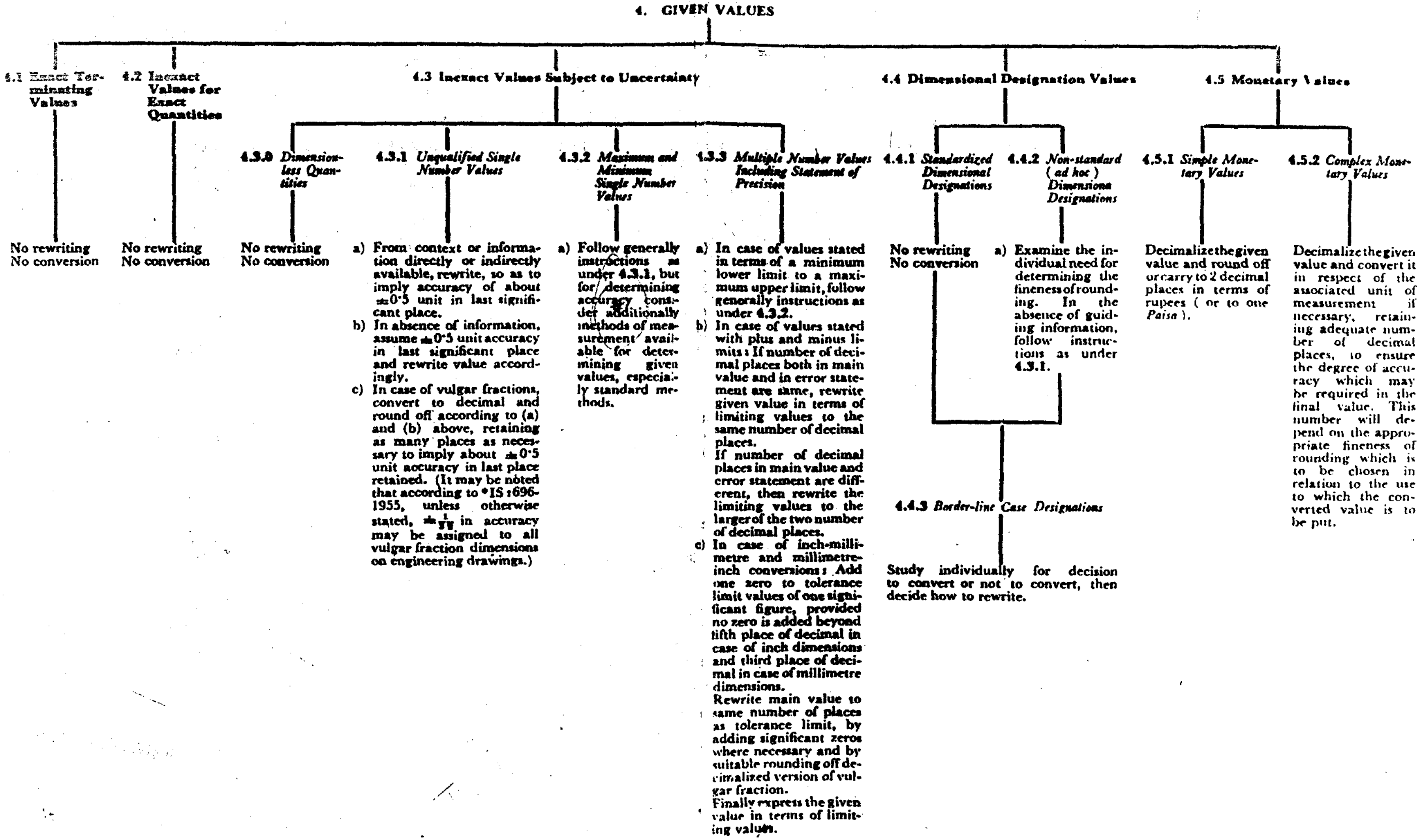
†The Bureau International des Poids et Measures adopted the value of normal atmosphere as 101 325 newton per metre^2 (exact).

‡These factors are based on the standard value of acceleration due to gravity 980·665 cm per sec^2 accepted internationally through the Bureau International des Poids et Measures.

APPENDIX B

(*Clause* 5.0)

BRIEF SUMMARY OF INSTRUCTIONS FOR REWRITING VALUES BEFORE CONVERSION IN THE LIGHT OF THEIR SIGNIFICANCE DISCUSSED UNDER 4



4. GIVEN VALUES

- **4.1 Exact Terminating Values**
  - No rewriting
  - No conversion
- **4.2 Inexact Values for Exact Quantities**
  - No rewriting
  - No conversion
- **4.3 Inexact Values Subject to Uncertainty**
  - 4.3.0 *Dimensionless Quantities*
    - No rewriting
    - No conversion
  - 4.3.1 *Unqualified Single Number Values*
    - a) From context or information directly or indirectly available, rewrite, so as to imply accuracy of about ±0·5 unit in last significant place.
    - b) In absence of information, assume ±0·5 unit accuracy in last significant place and rewrite value accordingly.
    - c) In case of vulgar fractions, convert to decimal and round off according to (a) and (b) above, retaining as many places as necessary to imply about ±0·5 unit accuracy in last place retained. (It may be noted that according to *IS : 696-1955, unless otherwise stated, $\pm\frac{1}{64}$ in accuracy may be assigned to all vulgar fraction dimensions on engineering drawings.)
  - 4.3.2 *Maximum and Minimum Single Number Values*
    - a) Follow generally instructions as under **4.3.1**, but for determining accuracy consider additionally methods of measurement available for determining given values, especially standard methods.
  - 4.3.3 *Multiple Number Values Including Statement of Precision*
    - a) In case of values stated in terms of a minimum lower limit to a maximum upper limit, follow generally instructions as under **4.3.2**.
    - b) In case of values stated with plus and minus limits : If number of decimal places both in main value and in error statement are same, rewrite given value in terms of limiting values to the same number of decimal places.

      If number of decimal places in main value and error statement are different, then rewrite the limiting values to the larger of the two number of decimal places.
    - c) In case of inch-millimetre and millimetre-inch conversions : Add one zero to tolerance limit values of one significant figure, provided no zero is added beyond fifth place of decimal in case of inch dimensions and third place of decimal in case of millimetre dimensions.

      Rewrite main value to same number of places as tolerance limit, by adding significant zeros where necessary and by suitable rounding off decimalized version of vulgar fraction.

      Finally express the given value in terms of limiting values.
- **4.4 Dimensional Designation Values**
  - 4.4.1 *Standardized Dimensional Designations*
    - No rewriting
    - No conversion
  - 4.4.2 *Non-standard (ad hoc) Dimensiona Designations*
    - a) Examine the individual need for determining the fineness of rounding. In the absence of guiding information, follow instructions as under **4.3.1**.
  - 4.4.3 *Border-line Case Designations*
    - Study individually for decision to convert or not to convert, then decide how to rewrite.
- **4.5 Monetary Values**
  - 4.5.1 *Simple Monetary Values*
    - Decimalize the given value and round off or carry to 2 decimal places in terms of rupees (or to one *Paisa*).
  - 4.5.2 *Complex Monetary Values*
    - Decimalize the given value and convert it in respect of the associated unit of measurement if necessary, retaining adequate number of decimal places, to ensure the degree of accuracy which may be required in the final value. This number will depend on the appropriate fineness of rounding which is to be chosen in relation to the use to which the converted value is to be put.

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